

Electrical Resistance

Objectives

- Identify the resistance of a resistor using the color code.
- Use a multimeter to measure the total resistance of a series circuit
- Solve for the values of three unknown resistors using systems of equations and matrices.
- Connect and determine the total resistance of a series circuit, a parallel circuit, and a combined circuit given the circuit diagrams.

Resources

Printed Sources

- Merrill, “Physics”, Chapter 23
Holt, “Modern Physics”, Chapter 22
Hewitt, “Conceptual Physics”, Chapter 22

Websites

- <http://www.xtronics.com/Kits/rcode.htm>
<http://ohmslaw.com/>
<http://www.purchon.co.uk/radio/ohmslaw.html>
<http://webhome.idirect.com/~jadams/electronics/series.htm>
http://jupiter.physics.lsa.umich.edu/106/content/parallel-series_circuits/SeriesParCircuits.html

Materials

- Resistors of various values (color coded)
- Multimeter
- Circuit Diagrams
- Connecting Wires (or wafer board or circuit board)
- Power Supply
- Ammeters
- Voltmeters
- Six Christmas lamps
- Aluminum foil

Instructional Concepts

Demonstrations

- How to use a multimeter
<http://csmt.msstate.edu/html/LearnToWork/projects/Resistance/index.html#Multimeter>
- Use 3 Christmas lamps connected in series and in parallel to introduce the circuits

Notes on the use of Ammeters

An ammeter must be placed in series with the circuit element whose current is to be measured. Thus an ideal ammeter would have zero resistance so that it would not affect the current flowing in the circuit in which the measurement is being made. Actual ammeters of reasonable quality have a very low resistance and this makes them susceptible to catastrophic damage. Ammeters must not be placed in parallel with batteries or with other power supplies or with resistors since the current through the ammeters under these conditions may destroy the meter mechanism.

A cheap convenient robust method of measuring currents is to place a good quality 1.00 ohm resistor in series with the elements with the elements whose current is to be measured (if their resistance is on the order of 50.0 ohms or greater) with a voltmeter across this 1.00 ohm resistor. It is obvious from Ohm's law that the current in amps through the 1.00 ohm resistor is numerically equal to the reading in volts on the voltmeter.

Project Development

Introducing Resistors

- a. The teacher will introduce and explain the resistor color code.
- b. Students will be divided into lab groups and each group will be given nine resistors to be used to construct three series resistor networks.
- c. Students will measure the value of each resistor with an ohmmeter and compare the measured value with that indicated by the color code.
- d. Students will determine the percent variance between the stated and measured values and will determine if the measured values of the resistors are within the tolerance indicated by the color code.
- e. Students will construct three series resistor networks in accordance with the resistor network diagrams. Students will measure the total resistance for each resistor network and compare that with the values calculated from the three resistors in each network.
- f. The students will write an expression for the relationship between R_T and R_1 , R_2 , and R_3 for a series resistor network.

Ohms Law

- a. Students will use an ammeter, voltmeter, power supply, and wires to connect a simple circuit containing one resistor. Students will measure and record the potential difference and current of the circuit.

Caution: Make sure that the ammeter is connected in series with the resistor to ensure that the current that flows into the ammeter also passes through the resistor

- b. Students will adjust the voltage and record the current measurement for each voltage.
- c. Students will plot a voltage versus current graph and calculate the slope of the line.
- d. Teacher will introduce ohm's law. Students will use ohm's law to calculate the resistance of the resistor. Students will determine the percent error by comparing the calculated resistance with the slope of the line.

Series Circuits

- a. Students will be given a diagram of three circuits containing 1,2, and 3 resistors in series.
- b. Students will use the voltage of the power supply and resistance of lab resistors to calculate the total resistance, current, and voltage drops for each circuit.
- c. Students will then connect the circuits and record measurement provided by the meters. Students will compare the calculated and measured values.
- d. Students will write a description of how to solve series circuit problems.

Solving for unknown resistors

- a. The teacher will explain a method for solving for unknown variables in a system of equations using matrices. He or she will then relate to the students how this same process can be applied to solving for unknown resistance in resistor networks.
- b. The teacher will prepare for each lab group, 3 sets of 5 resistors of the same value. He or she will cover each type of resistor with tape and label all 5 of the same value as A, then the next set of 5 as B and finally the last set as C so that students cannot identify the resistors using the color code on the resistors.
- c. Students will then build a series network of nine resistors using all three types of resistors in differing quantities and measure the total resistance across each network.
- d. The students will repeat the process and build two additional series networks of nine resistors using different quantities for each type of resistor.

The equations for the three networks might appear as follows:

$$3A + 2B + 4C = 115\Omega$$

$$2A + 4B + 3C = 110\Omega$$

$$5A + 3B + 1C = 75\Omega$$

- e. Students will solve the system of equations using matrices. The solution for the networks shown is: $A = 5\Omega$ $B = 10\Omega$ $C = 20\Omega$

Parallel Circuits

- Students will be given a diagram of three circuits containing 1, 2, and 3 resistors in parallel.
- Students will use the voltage of the power supply and resistance of lab resistors to calculate the total resistance, current, and voltage drops for each circuit.
- Students will then connect the circuits and record measurement provided by the meters. Students will compare the calculated and measured values.
- Students will write a description of how to solve series circuit problems.

Solving for Unknown Resistors

- Students will be divided into lab groups to connect a series circuit given 3 resistors of unknown values. Use tape to cover the color code.
- Students will then use the measured values for current (I) and the voltage (V) across each resistor to calculate the resistance of each resistor using Ohm's Law.
- Students will compare the experimentally determined values for R_1 , R_2 , and R_3 with the values given by their color code (tape removed)
- Students will connect the same resistors in parallel and determine the individual and total resistance of the network using the measured values of V across each resistor and the value for I in each branch of the circuit; as well as V_T and I_T . Note that the ammeter must be moved to different positions in the circuit.

Is the resistance the same in series and parallel?

Combined Circuits

- Given a combination series/parallel circuit diagram, students will calculate the total resistance, total current, the voltage drops across each resistor and the current in each branch. The values for V_T and R_1 , R_2 and R_3 are known.
- Students will connect the circuit and measure the values for I_T , R_T and V_T , V_2 , V_3 , I_1 , I_2 and I_3 . The value for R_T is determined by dividing V_T by I_T . Students will compare their experimental values obtained with calculated values determined in (a).
- Students will then replace a resistor of known value with a resistor of unknown value and determine the value of the new resistor.

Applications in the Workplace

Many industries need employees that have the knowledge and skills necessary to install, operate, troubleshoot, service and repair electrical equipment. A basic knowledge of the relationship between voltage, current, and resistance is basic to an understanding of electrical systems. The real life applications of this activity vary from household electrical wiring to the many small circuits used in the amplifiers and speaker systems built at Peavey Electronics.

Integration Across the Curriculum

Faculty from physics and mathematics could identify a part of the project relevant to their discipline and could contribute to the success of the project. The art class could prepare resistor color code chart for the labs.